Bringing atom-thick materials to the millimeter scale

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FIGURE 1
Secondary electron scanning electron microscopy (SE-SEM) and optical images of graphene grown on oxidation/reduction treated copper, showing millimeter-sized hexagonal crystals of single-layer graphene.

FIGURE 2
SE-SEM and optical images of free-standing few-layered graphene membranes obtained by the newly developed method, showing the increased difficulty of the transfer process for diameter membranes and an optically clear 4-mm-wided transparent graphene film.

Graphene, the 2D single layer of carbon atoms arranged in a honeycomb pattern, is one of the most studied materials nowadays due to its outstanding properties and its role as a platform to study new physics phenomena. To provide practical applications of this material, upscaling of both the production methods and transfer techniques is required. To this end, in 2020, the I3N | Carbon-based Materials and Laser Processing Group has published two works regarding the synthesis and processing of graphene at the millimeter scale, pursuing two distinct strategies. In the first one, the role of oxygen in the pre-treatment of copper substrates for chemical vapor deposition (CVD) of graphene and its impact on the crystalline quality and crystal domain dimensions was explored [1]. By a simple in-situ prior oxidation and subsequent reduction of the substrate before growth, >2-mm-wide single-layer graphene crystals were obtained (Fig. 1), through removal of carbon impurities from the copper bulk. This, along with an optimized synthesis recipe, allowed to achieve improved electrical transport properties compared to the synthesis without an oxidation/reduction approach. In the second strategy, a novel transfer technique has been developed, enabling the suspension of few-layered graphene films over 4-mm-wide cavities (Fig. 2), doubling the previous literature record for suspended area per number of layers [2]. This is equivalent to suspending a sheet as thin as regular office paper over an area the size of a football field, made possible by exploiting a new approach to remove the graphene transfer supporting layer in vacuum. These suspended membranes were then used to build a prototype condenser microphone with an enhanced specific response. Overall, both these strategies have advanced the state of the art in the synthesis and transfer of graphene, paving the way for future application in a wide range of fields, such as electronic, photonic and sensor applications.

[1] Bohdan Kulyk, Alexandre F. Carvalho, António J.S. Fernandes, Florinda M. Costa., *Millimeter sized graphene domains through in situ oxidation/reduction treatment of the copper substrate*, Carbon, 169 (2020) 403-415. DOI: 10.1016/j.carbon.2020.08.002.
[2] A. F. Carvalho, António J.S. Fernandes, Mohamed Ben Hassine, Paulo Ferreira, Elvira Fortunato e Florinda M. Costa, *Millimeter-sized few-layer suspended graphene membranes*, Appl. Mater. Today, 21 (2020) 100879. DOI: 10.1016/j.apmt.2020.100879.

Figure 1

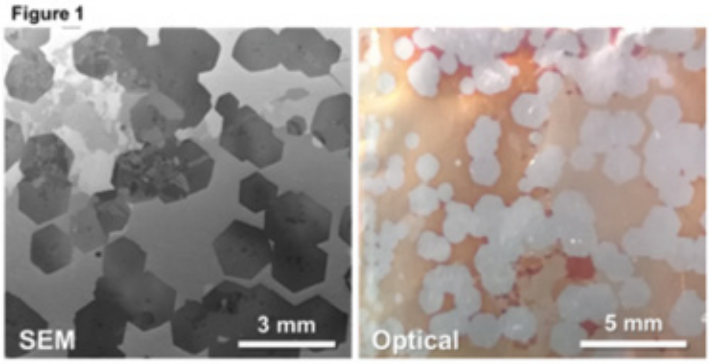

Figure 2